

**ECOLOGY, DISTRIBUTION, AND CONSERVATION BIOLOGY OF THE
TIGER BEETLE *CICINDELA PATRUELA CONSENTANEA* DEJEAN
(COLEOPTERA: CARABIDAE: CICINDELINAE)**

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Abstract.—The tiger beetle *Cicindela patruela consentanea* Dejean is known only from the mid-Atlantic coastal plain of the United States, where it is closely associated with pine and oak barrens ecosystems. Historic collecting records document the past presence of this subspecies at multiple sites in New Jersey and Long Island, while single specimens are also known from Delaware, Maryland, and Pennsylvania. This tiger beetle apparently has been extirpated from much of its former range, and extant populations are known only from sites within state forests and state wildlife management areas in the Pine Barrens region of New Jersey. Soil, vegetation, and forest stand characteristics were studied at four sites occupied by populations of *C. p. consentanea* in 2004, 2005, and 2006. Observations on adult biology and population dynamics are reported. Adult beetles were active along sandy trails and firebreaks in pine-oak woodlands dominated by *Pinus rigida* Miller (Pinaceae) and several *Quercus* species (Fagaceae), primarily *Quercus ilicifolia* Wangenheim. The use of prescribed fire as a forest management tool was evident at three of the four sites. Management activities which may benefit these populations include the continuation of prescribed burns as well as routine trail and firebreak maintenance.

Key Words: *Cicindela patruela*, tiger beetle, conservation, distribution, habitat characterization, habitat management

The tiger beetle *Cicindela patruela* Dejean is distributed throughout much of northeastern North America, where it is associated with pine or oak barrens ecosystems on sandy soils. Typically occurring in small, localized populations, this species has become the subject of conservation concern in recent years. Extirpations of *C. patruela* populations have been reported in New York (McCabe 1995), the District of Columbia, and Maryland (Glaser 1984, Mawdsley 2005), and this species currently is listed as “Endangered” by the

states of Maryland and Massachusetts (Maryland Department of Natural Resources 2003, Massachusetts Division of Fisheries and Wildlife 2004).

Three subspecies are recognized within *C. patruela* (Werner 1993, Pearson et al. 2006). The nominate form, green with white elytral markings, occurs sporadically from Massachusetts west to Minnesota and south through the Appalachian Mountains to northern Georgia (Kaulbars and Freitag 1993). *Cicindela patruela huberi* Johnson from central Wisconsin differs from the nom-

inate form in having brown or black dorsal coloration with white markings (Johnson 1989). *Cicindela patruela consentanea* Dejean, a black form with white elytral markings, was reported historically from the Atlantic coastal plain from Long Island south through New Jersey to the Delmarva peninsula (Kaulbars and Freitag 1993, Freitag 1999).

Recent studies have investigated various aspects of the biology and distribution of both the nominate subspecies and *C. p. huberi* (Knisley et al. 1990; Willis 2000, 2001). This paper summarizes the known information regarding the biology and distribution of *C. p. consentanea*, provides a more robust characterization of the habitat at sites occupied by populations of this subspecies, and identifies potential management strategies that may help insure the long-term survival of this tiger beetle.

MATERIALS AND METHODS

For this study, I examined the complete collections of *Cicindela patruela* in the American Museum of Natural History (AMNH) and the National Museum of Natural History, Smithsonian Institution (NMNH), which included 287 specimens of *C. p. consentanea*. Ninety-two of the specimens in both museums were collected during intensive searches for this subspecies in the 1970s and 1980s by H. Boyd, D. Pearson, J. Sheppard, J. Stamatov, and E. Stiles. Howard Boyd (in litt.) also graciously provided me with his own, unpublished data regarding these latter collections, which included data on an additional 547 specimens which were captured between 1971 and 1982.

From museum specimen labels, I was able to identify four specific sites in Burlington and Ocean counties, New Jersey, at which specimens of *C. p. consentanea* were collected in the 1970s and 1980s. During May and September, 2004, May, July, and September, 2005,

and May, 2006, I visited all four of these sites in search of adult *C. p. consentanea*. On these trips, I also examined sixteen additional sites in the New Jersey Pine Barrens which were occupied by populations of other tiger beetle species. These additional sites are mostly unpaved sand roads and trails, although power line rights-of-way, abandoned sand pits, and roadside clearings were also included. I selected the dates of these trips (except for the July visit) to coincide with the greatest number of past collections of *C. p. consentanea*, as indicated by museum specimen labels.

Because *C. p. consentanea* is closely associated with woodlands, I was interested in determining whether certain features of forest stand composition and structure were characteristic of sites occupied by this subspecies. Accordingly, I used standard techniques to assess forest stand composition and quantify stand structure at the four sites where adults of *C. p. consentanea* were found. Specific measurements taken at each site included: diameter at breast height (DBH, measured 137 cm above mean ground level) of a random sample of 10 or more *Pinus rigida* and 10 or more *Quercus* spp. along trails where adults were observed; stand basal area, estimated as the average of measurements made using a "cruiser's crutch" tool at 10 randomly selected points along occupied paths; maximum heights of at least 10 randomly selected understory shrubs; and the width of paths on which adult beetles were found, measured at 5 randomly selected points (these paths tended to be fairly uniform in width; thus, only a smaller number of measurements was taken).

RESULTS

Historic Distribution

The following list of sites represents the known historic distribution of *C. p.*

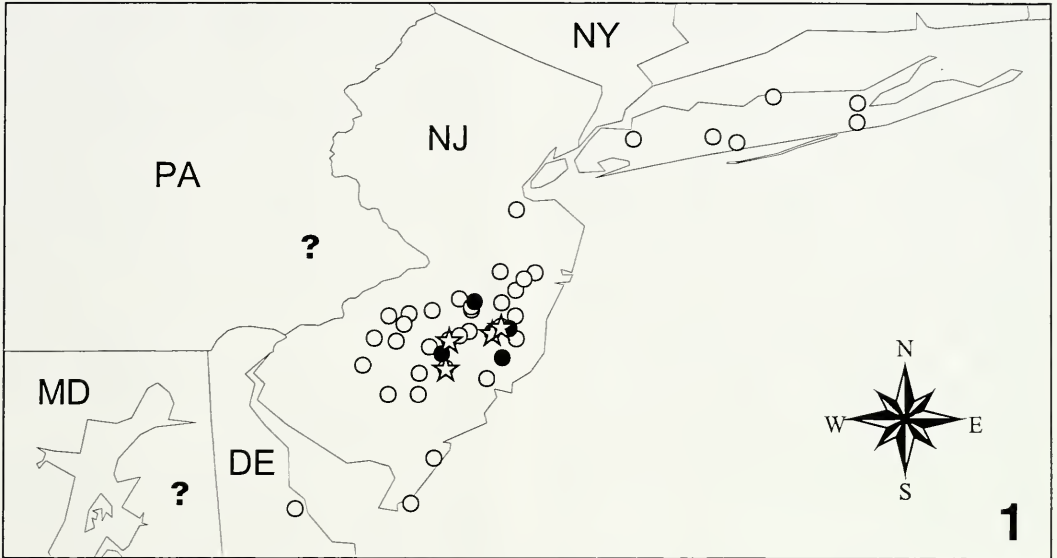


Fig. 1. Collecting localities for *Cicindela patruela consentanea*, mapped using ArcView Geographic Information System software. Open circles indicate historic (pre-1970) collections; closed circles indicate collections between 1971 and 1982; open stars are the author's study sites; question marks indicate state records only.

consentanea. Boyd (1978) and Leonard (1926) have summarized many of the older records from New Jersey and New York based on material from multiple museum collections. Localities followed by AMNH or NMNH represent new records from these museum collections. A Geographic Information System (GIS) map showing these localities is provided as Fig. 1.

DELAWARE: Sussex County: Milford (Glaser 1984; Knisley and Schultz 1997).

MARYLAND: No locality specified (NMNH).

NEW JERSEY: Atlantic County: Buena, DaCosta, Weymouth. Burlington County: Atsion, Batona Trail (AMNH), Batsto (NMNH), Browns Mills, Carranza Memorial, Chatsworth, Harris Station, Marlton, Medford, Mt. Misery, New Gretna, Quaker Bridge, Retreat, Taunton Lakes, Upton Station, West Plains, Whitesbog. Camden County: Atco, Pine Hill. Cape May County: Seaville, Wildwood. Gloucester County:

Fries Mill. Middlesex County: Brown-town, 13-Oak Forest. Ocean County: Bamber Lake, Brackenville, Brookville, Cassville, Cedar Bridge, East Plains, Lacey Township, Lakehurst, Lakewood, Manchester, Whitesville, Whiting (Boyd 1978).

NEW YORK: Queens County: Alley Pond (Malkin 1941). Suffolk County: Bay Shore (NMNH), Port Jefferson, Riverhead, Westhampton, Wyandanch (Leonard 1926).

PENNSYLVANIA: No locality specified (NMNH).

There are also unconfirmed reports of specimens of *C. p. consentanea* from Rhode Island and Massachusetts (Boyd 1978 and in litt.). The museum specimens that I examined from these two states were all from the nominate form, *C. p. patruela*. Leonard and Bell (1999) reviewed the tiger beetle fauna of these states in greater detail and also examined historic specimens from the relevant regional collections; these authors likewise only report the nominate subspecies

of *C. patruela* from Massachusetts and Rhode Island.

Present-Day Distribution

Cicindela patruela consentanea has apparently been extirpated from much of its historic range. As discussed in more detail below, recent (post-1941) records of this tiger beetle are only from the Pine Barrens region of New Jersey. However, this subspecies appears to be widely distributed within this region and may even be locally abundant at certain sites. Fig. 1 indicates localities at which this species has been collected since 1971, including the author's four study sites.

The records of *C. p. consentanea* from Delaware, Maryland, and Pennsylvania are based in each case on single specimens, which in the case of the Maryland and Pennsylvania specimens in NMNH are undated but clearly very old. Given the lack of any recent records from these three states (Knisley and Schultz 1997, Boyd 1978, NatureServe 2005), it is doubtful whether this subspecies still occurs in any of them.

If *C. p. consentanea* was ever found in either Rhode Island or Massachusetts, it is no longer present. The species *C. patruela* is considered extirpated from Rhode Island and only a small population of the nominate subspecies *C. p. patruela* survives at the Myles Standish State Forest in Massachusetts (Leonard and Bell 1999).

The last report of *C. p. consentanea* from New York is that of Malkin (1941). There is no recent material of this subspecies from Long Island in AMNH, no other recent reports from New York (NatureServe 2005) and thus this subspecies should probably be considered extirpated from the state.

Recent (post-1941) records of *C. p. consentanea* are all from the core Pine Barrens region of central New Jersey, principally sites in Burlington and Ocean

counties. Howard Boyd and other tiger beetle workers (D. Pearson, J. Sheppard, J. Stamatov, E. Stiles) spent considerable time and energy searching for this subspecies in the 1970s and 1980s, with the resulting discovery of a number of localized populations (Boyd 1973, 1978). The best current estimate is that there are approximately 10–20 occupied sites within the Pine Barrens region (NatureServe 2005), although, as discussed at the end of this paper, there are reasons to suspect that this may be an underestimate.

The most recent (post-1970) collecting sites for this tiger beetle are widely scattered throughout the Pine Barrens region and it seems probable that *C. p. consentanea* is generally distributed throughout this area. Some sites have evidently supported large populations in recent years, as demonstrated by collecting records provided to the author by Howard Boyd from the 1970s and early 1980s, which indicate that up to 57 specimens of this tiger beetle were collected at one site on a single day. The recent collecting sites for *C. p. consentanea* are all located within tracts of land in Burlington and Ocean counties which are owned by the State of New Jersey and managed for conservation purposes, including Bass River State Forest, Brendon T. Byrne (formerly Lebanon) State Forest, Greenwood Forest State Wildlife Management Area, Stafford Forge State Wildlife Management Area, and the Wharton State Forest.

It should be noted that characteristic Pine Barrens vegetation can still be found at sites in several of the other New Jersey counties which have historic records of *C. p. consentanea* (NatureServe 2005). Because these areas have not been surveyed recently for *C. p. consentanea*, it is not possible to state at this time whether or not this tiger beetle still occurs in these counties.

Habitat Characterization

I found adults of *C. p. consentanea* at four sites in New Jersey during field trips in 2004, 2005, and 2006. Two sites where I found adults were locations at which specimens of *C. p. consentanea* had been collected in the 1970s and 1980s. Three sites are located in Burlington County, while the fourth is located in Ocean County. Adults were found during all six field trips.

In addition to the four sites which were occupied by populations of this subspecies, I observed single adult females on two separate occasions on large, heavily-trafficked sand roads near two of the occupied sites in May, 2005, and May, 2006. As discussed below, I interpret the occurrences of these isolated individuals in what are evidently marginal or unsuitable habitats as representing dispersal events, rather than established populations.

To protect this subspecies from possible over-collecting, the exact locations of the occupied sites will be described only in general terms. One of these sites is a sand trail within the Bass River State Forest, another site is a sandy trail near Batsto Village in the Wharton State Forest, the third site is a firebreak and associated clearing in the Greenwood Forest State Wildlife Management Area, while the fourth site is a sandy trail near Tabernacle in the Wharton State Forest.

All four sites are located in pine-oak woodlands. The dominant tree species at the Batsto site are *Pinus rigida* Miller (Pinaceae) and *Quercus marilandica* (L.) Münchhausen, with *Q. coccinea* Münchhausen and *Q. falcata* Michaux (all Fagaceae) also present. The stands at the Bass River and Greenwood Forest sites consist of *P. rigida* and *Q. ilicifolia* Wangenheim, with *Q. stellata* Münchhausen also present at Greenwood Forest. The Tabernacle site is located in an almost pure stand of *P. rigida*, with

widely scattered *Q. ilicifolia*. The Batsto, Greenwood Forest, and Tabernacle sites are open woodlands, with mature trees (> 8 meters in height), a relatively open canopy, and a well-defined understory of short (< 1 meter in height) shrubs of species in the genera *Vaccinium* and *Gaylussacia* (Ericaceae). The Bass River site is located in a "scrub" forest composed of short (< 4 meters in height) individuals of *P. rigida* and *Q. ilicifolia*, with intermingled shrubs of the genera *Kalmia* (Ericaceae), *Vaccinium*, and *Gaylussacia*. Canopy cover is nearly 100% in the scrub forest. Sedges (*Carex* spp., Cyperaceae), mosses, and lichens are found along the trails and roads at all four sites.

Forest stand measurements such as basal area and average diameter at breast height (DBH) of the canopy trees varied widely between sites (Table 1), suggesting that these variables may be less important to the beetles than other factors such as substrate type or the presence of recent fire. However, it should be noted that the greatest numbers of adult beetles were observed at the Greenwood Forest and Tabernacle sites, which are very similar in terms of their forest stand characteristics.

Exposed substrate at all four sites consists of unconsolidated fine white sand with intermixed fine dark organic matter, giving the substrate an overall grey appearance. Larger organic matter (dead leaves, needles, twigs, branches, cinders) was distributed sparsely over the surface of the trails. At all four sites the cover of organic matter on the forest floor proper was 100%. As noted above, single adult females were encountered on two separate occasions on large, heavily-trafficked sand roads. In both of these cases, the substrate consisted of unconsolidated yellow sand with intermixed small (< 2 cm diameter) rounded pebbles. Howard Boyd, who has had more experience with this subspecies than

Table 1. Physical attributes and forest stand measurements of four sites occupied by populations of *Cicindela patriula consentanea*. All figures are averages of multiple measurements.

Site	Average DBH of Canopy Trees		Stand Basal Area	Average Understory Shrub Height	Average Path Width	Substrate Exposed in Trails / Paths	Recent Fire?
	<i>Pinus rigida</i>	<i>Quercus</i> spp.					
Bass River	4.3 cm	2.3 cm	< 2 m ² /ha	44 cm	132 cm	White sand intermixed with fine, black organic matter	No
Batsto	30 cm	29 cm	22 m ² /ha	44 cm	137 cm	As above	Yes
Greenwood Forest	13 cm	3.0 cm	9.0 m ² /ha	51 cm	204 cm	As above	Yes
Tabernacle	13 cm	3.9 cm	14 m ² /ha	61 cm	119 cm	As above	Yes

anyone else, has noted a general association of *C. p. consentanea* with coarser substrates (Boyd 1973, 1978).

Three of the four sites receive regular human use. Human traffic was not observed at the Bass River site during this study, but adjacent roads are heavily used by motorized vehicles and are also regularly maintained by heavy equipment. The sand trail at the Batsto site receives moderate pedestrian and bicycle traffic but no motorized vehicle use. The firebreak at the Greenwood Forest site was actively maintained by a bulldozer between the 2004 and 2005 field seasons. The sand trail at the Tabernacle site receives heavy horse and pedestrian traffic but no motorized vehicle use.

The use of light ground fire as a general forest management tool is evident at the Batsto, Greenwood Forest, and Tabernacle sites. Evidence of such fires includes superficial basal fire scars on trunks of the canopy trees and the presence of ash and cinders on the ground. The woodland along one side of the Greenwood Forest site was burned between the 2004 and 2005 field seasons, killing the aboveground portions of the understory vegetation and leaving superficial fire scars to 1.2 meters on the trunks of the canopy trees. This burning had no evident impacts on the beetle population, as the numbers of adult beetles observed at this site were roughly

the same in September, 2004, and May, 2005. Although evidence of recent burning was not observed at the Bass River site during this project, this general area is known to have an average fire frequency of 10–20 years (Boyd 1991). Leng (1902b) noted an association of *C. p. consentanea* with “burnt ground” near Lakehurst. Taken together, these observations suggest that this tiger beetle may have a more general association with burned areas.

Adult Biology

Adults of *C. p. consentanea* are quite wary, perhaps more so than any of the other, more common tiger beetle species in the New Jersey Pine Barrens. They are difficult to locate in the field, as their black and white coloration is strongly cryptic on the grey sandy trails and adjoining dark areas of moss, lichens, and organic debris. When first approached, adults will typically stop moving and remain motionless until they are approached more closely, at which time they fly rapidly away from the disturbance. As noted by Boyd (1973, 1978) their flight may take them into low vegetation where they are extremely difficult to re-locate. On linear trails, I have found that adults will often fly 5–10 meters ahead and land on the trail or along its sides. They may tumble upon landing, much like *C. formosa*

generosa Dejean, and some individuals may make a buzzing noise during flight. If they land in the open, adults typically remain motionless for some time and are very difficult to find until they move again. Upon landing, adults may also run short distances to conceal themselves under vegetation or organic debris.

Boyd (1973, 1978) noted that adults of *C. p. consentanea* were most active in the morning and again in mid-afternoon, an observation which is supported by my own field experiences. During mid-day and in the evening, adults conceal themselves under organic debris or low vegetation.

Predation on small ants was observed several times in the field; predatory behaviors are as described for other tiger beetles (Knisley and Schultz 1997).

Reproductive behaviors (mating, mate guarding, and female testing of substrate prior to oviposition) were only observed during the May field trips. Oviposition was not observed, suggesting that it may occur in areas away from the sandy trails where the adults are most commonly found, as is the case with other subspecies of *C. patruela* (Knisley et al. 1990; Willis 2000, 2001).

Other species of tiger beetles were often found at sites with *C. p. consentanea*. The most frequently encountered species included *C. purpurea purpurea* Olivier (2 sites, but abundant at both), *C. scutellaris rugifrons* Dejean and *C. tranquebarica tranquebarica* Herbst (both present at 3 sites, but in smaller numbers), and also *C. sexguttata* Fabricius (common at 2 sites in May only). Species found in small numbers included *C. formosa generosa* Dejean (1 individual at 1 site) and *C. punctulata punctulata* Olivier (2 individuals each at 2 sites).

Larval Biology

Larval biology was not studied in detail. In general, larval burrows were

not found on the sand trails occupied by the adult beetles at any of the study sites. The Greenwood Forest site (which had the greatest number of active adults of *C. p. consentanea* of any site visited during this study, and where *C. p. consentanea* was the most abundant tiger beetle during my site visits) was carefully searched for larvae and larval burrows. At this site, larvae and burrows of multiple tiger beetle species, possibly including *C. p. consentanea*, were observed in a small area of sandy soil in a clearing covered with small pebbles (< 2 cm diameter), lichens, mosses, and sedges. The larvae of other subspecies of *C. patruela* are known to occur in similar microhabitats located away from the sand trails where adults are found (Knisley et al. 1990, Willis 2000). Further investigations of the larval habitats and larval biology of this subspecies are needed.

A specimen in AMNH from Mt. Misery is labeled "Reared from larvae," suggesting that captive rearing of this tiger beetle is possible.

The length of the life cycle in *C. p. consentanea* is not known, but is probably at least two years, as is the case in other subspecies of *C. patruela* (Knisley and Schultz 1997).

Observations on Population Dynamics

Adult activity in *C. p. consentanea* is on a "spring-fall" cycle, as is the case with the other subspecies of *C. patruela* (Knisley and Schultz 1997; Willis 2000, 2001). Adults emerge in late summer, are active for several weeks, and then dig burrows in loose sand or under objects on the ground where they spend the winter. In the spring, they re-emerge, mate, and the females oviposit. Based on museum specimens and other collecting records (Fig. 2), fall activity in *C. p. consentanea* commences during the last week in August and peaks in mid-September, with occasional adults found

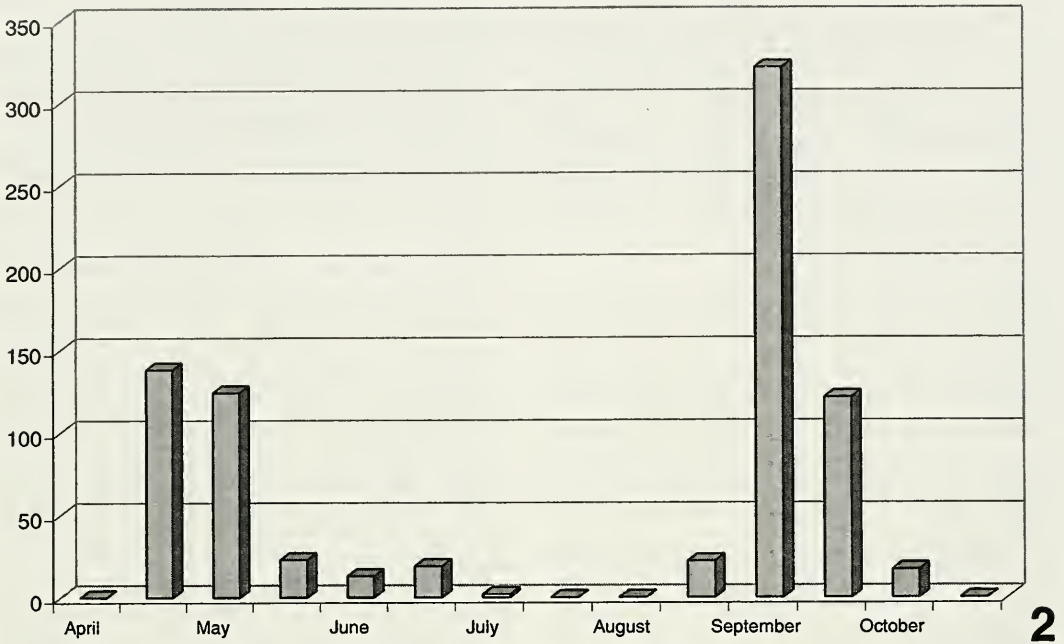


Fig. 2. Collecting dates for *Cicindela patruela consentanea*, based on specimens in AMNH and NMNH and additional records provided by Howard P. Boyd, summed across all years and tabulated semi-monthly. The vertical axis indicates numbers of specimens.

as late as October 12. Spring activity begins mid-April, with adult beetles found until mid-June and a few lasting into early July.

Specimen labels from AMNH and NMNH as well as additional collecting records supplied by Howard Boyd suggest that this subspecies is somewhat more abundant in the fall than in the spring. Across all years, 319 specimens were collected during the interval March 30 to July 5, while 481 specimens were collected during the interval August 20 to October 12. A similar pattern is exhibited by the graph of 135 collecting records presented by Kaulbars and Freitag (1993). There may be a bias towards fall collecting records, due to the coincidence of the fall activity period with the U.S. "Labor Day" holiday weekend, when more collectors may be active.

For tiger beetle species such as *C. patruela* which have multi-year life cy-

cles, the numbers of adults observed at a particular site may fluctuate from year to year, sometimes quite dramatically. For example, *C. p. consentanea* adults were abundant at the Greenwood Forest site in September, 2004, and May, 2005, with up to 12 individuals observed on a single day. In contrast, very few adults were observed at this same site in September, 2005, and May, 2006, with at most two individuals observed on a single day. The beetles in September, 2004, and May, 2005, were presumably part of the same generational cohort, while those in September, 2005, and May, 2006, may represent a different, smaller cohort; alternatively, these may simply be individuals from the previous season's cohort exhibiting delayed emergence (see discussion in Knisley and Schultz 1997). Such fluctuation in population size between successive years is probably to be expected in this species and should be taken into account when

designing surveys or monitoring protocols.

The sex ratio in *C. p. consentanea* is evidently close to 1:1; of the 287 museum specimens examined, 148 were males and 139 were females.

As with other tiger beetles (Knisley and Schultz 1997), there is some evidence to suggest that adults of *C. p. consentanea* may disperse from occupied sites. Adults are strong flyers and certainly have the capability to disperse long distances. The observations noted above of single beetles on heavily trafficked sand roads in May are perhaps best interpreted as examples of such dispersal. On the subject of dispersal, it is interesting to note that most of the specimens in AMNH and NMNH represent unique, single-specimen collecting events, and that of the 23 localities for this subspecies represented in NMNH, 14 are represented by single specimens only. Similar patterns are evident in data presented by Boyd (1978). It seems possible that some of these collections may represent dispersing individuals, rather than established populations.

It is difficult to estimate current population size for *C. p. consentanea*. Obtaining an accurate count of active adults at a particular site is challenging, given the beetles' cryptic coloration and readiness to take flight at the slightest disturbance. Under even the most optimal circumstances, visual surveys of adult tiger beetles will underestimate population size by 50% to 80%, with lower accuracy for woodland taxa (Knisley and Schultz 1997). My own counts of adult beetles at sites in the Pine Barrens are undoubtedly underestimates. That said, the individual populations of *C. p. consentanea* which I observed are small. The greatest number of adults that I observed at one site on a single day was 12 at the Greenwood Forest site in September, 2004. More typical observations were of one or two beetles on

a single day at an occupied site. Given the strong likelihood of dispersal by adults, it is probable that these small, scattered populations are actually part of larger meta-populations. If this is in fact the case, the effective population size would be larger than the number of beetles observed at any one site.

Long-term population trends of *C. p. consentanea* in New Jersey are also difficult to assess. This tiger beetle has always been a challenge for collectors to find in the field, and thus it is difficult to infer past population sizes from either published accounts or museum specimen records. Leng (1902a) says "it is the least abundant of the Pine Barrens Cicindelae, but under favorable circumstances a dozen may be taken in a day," an observation which is certainly consistent with my own recent experiences. Howard Boyd (1973) introduces his discussion of *C. p. consentanea* with the statement "this is a very elusive species" and indicates that he had only encountered it twice in the period 1940 to 1970. However, from 1971 through the early 1980s, Boyd and other collectors found *C. p. consentanea* in large numbers at a few sites, with as many as 57 specimens collected on a single day (Boyd 1973, 1978, and in litt.).

Discussion and Management Recommendations

Since *C. p. consentanea* has evidently been extirpated from much of its former range, every effort should be made to insure that this subspecies is not driven to extinction through human activities. Fortunately, much of the remaining occupied or potential habitat for this subspecies has already been protected by the State of New Jersey and is being actively managed in a manner that should insure the long-term viability of the beetle populations.

The most important management recommendation for *C. p. consentanea* is for the continued protection and wise man-

agement of the occupied habitats. Sites at which this subspecies has been collected within the past thirty years are all within areas which are owned and actively managed by the State of New Jersey for conservation purposes. These areas include Bass River State Forest, Brendon T. Byrne (formerly Lebanon) State Forest, Greenwood Forest State Wildlife Management Area, Stafford Forge State Wildlife Management Area, and the Wharton State Forest. Although I am not aware of occupied sites on private lands, any such sites that are identified through future surveys should be made priority locations for land protection efforts (fee title acquisition and/or protective conservation easements) to prevent the destruction of the natural vegetative communities through residential or commercial development. Such development has been responsible for extirpating *C. patruela* populations elsewhere (Mawdsley 2005) and would undoubtedly eliminate populations of *C. p. consentanea* were it to occur on occupied sites.

Beyond land protection, the ongoing management of pine and oak barrens sites is essential to prevent canopy closure and the loss of open barrens habitat (Boyd 1991, Knisley and Hill 1992). Fortunately the State of New Jersey has a long history of management activities such as prescribed fire, thinning of forest stands, and regular maintenance of firebreaks and sand roads in the Pine Barrens, activities which are primarily directed at preventing catastrophic wildfires (Boyd 1991). On the basis of the habitat characterization which has been developed in this study, it is clear that these forest management activities probably benefit *C. p. consentanea*. Particularly valuable activities include the use of low-intensity prescribed burns to reduce understory vegetation and woody debris, as well as the construction and periodic maintenance of firebreaks

and sand trails. Continuation of these management practices should help to maintain existing habitats and create new areas of suitable habitat for *C. p. consentanea*.

Given the highly elusive nature of the adult beetles, modest collecting activities probably pose no significant threat to *C. p. consentanea*. However, since this tiger beetle evidently has small population sizes, collectors should refrain from taking large series of specimens from occupied sites. The collection of small numbers of voucher specimens, especially from newly discovered sites, should be encouraged as long as these specimens will be deposited in permanent museum collections. The timing of collecting activities is also important, given that mating and oviposition apparently occur only in the spring and early summer. In particular, collectors should avoid taking large series of beetles in the fall and spring before the adult beetles have had a chance to deposit at least some of their eggs.

Further Research

Key research needs for *C. p. consentanea* include a more detailed study of larval biology and larval habitats as well as more comprehensive surveys for adult beetles in areas of potential habitat in New Jersey. Based on my field experiences, I suspect that there are other occupied sites within the core Pine Barrens area which have not yet come to the attention of collectors. There are literally hundreds of miles of sandy woodland trails on state, private, and federal lands in south-central New Jersey. Many of these trails have probably not been searched recently (if at all) for *C. p. consentanea*. It is quite possible that more in-depth surveys will reveal that this beetle is present at more sites or in larger numbers than are currently known. As precedent, I would cite the experience of Willis (2000, 2001) with *C.*

p. huberi in Wisconsin. Prior to Willis's collecting effort in 1999 and 2000, *C. p. huberi* was known from only three small sites in central Wisconsin. Through careful surveys, Willis found adults of this subspecies at an additional 32 sites. To judge from the number of specimens collected (up to 44 specimens collected on the same date at one site), some of these newly discovered *C. p. huberi* populations are quite large. Further survey work, particularly in larger forest blocks such as the Wharton State Forest and also in areas seldom visited by collectors such as Fort Dix and the Lakehurst Naval Air Engineering Station, is needed to clarify the size and status of the *C. p. consentanea* populations in the New Jersey Pine Barrens.

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